TU4C-3

Waveguide Multimode Directional Coupler for Harvesting Harmonic Power from the Output of Traveling-Wave Tube Amplifiers

Rainee N. Simons and Edwin G. Wintucky
NASA Glenn Research Center
Cleveland, OH 44135, USA

Email: Rainee.N.Simons@nasa.gov

June 6, 2017
Outline

• Introduction - Motivation
• Benefits & Challenges
• Waveguide Multimode Directional Coupler
  – Coupler Design
  – Coupler Fabrication
  – Coupler Characterization
• Conclusions
• Acknowledgement
Introduction – Motivation

• Growing user community
  – Congestion in the traditional Ku, K, and Ka frequency bands designated for space-to-ground data communications

• Next available bands above Ka-band are the Q-band (37-42 GHz) and E-band (71-76 GHz)
Benefits of Migrating to Higher Frequencies

- Allocated bandwidth at Q-band & E-band is in excess of 4 GHz, which can enhance throughput by 10X or higher
  - Competitive with terrestrial fiber optic & wireless service in terms of cost per transmitted bit
- Narrower beam width & smaller spot size
- Greater frequency reuse & spectral efficiency
Challenges

• Lack of rigorous studies to understand atmospheric effects on radio wave propagation at Q-band & E-band
  – These studies are essential for the design of a robust system for deployment in space
Challenges (continued)

• A wide band beacon transmitter has to be deployed on a satellite
  – Ground receivers have to be dispersed over climate zones of interest
  – Statistical data on rain attenuation, fading, change in refractive index, scintillation, depolarization effects, etc., have to be acquired for a period of 3 to 5 years
High Power Amplifier Harmonics

\[ P_{\text{in}}(f_0) \quad \rightarrow \quad \text{High Power Amplifier} \quad \rightarrow \quad P_{\text{out}}(f_0, 2f_0, 3f_0, \ldots) \]

**Example:** Measured values range from 20 to 23 dBm (100 to 200 mW) for the 40 W K-band TWTA

TWTAs on board satellites for data transmission operate with constant envelope type waveform (for e.g. QPSK) and at saturation for peak efficiency.
Waveguide Multimode Directional Coupler (MDC)
Fabricated Ku-Band/Ka-Band Waveguide MDC
Test Circuit for Measurement of Power at Fundamental ($f_0$) & Second Harmonic (2$f_0$)
Experimental Setup - Ku-Band/Ka-Band MDC Tests

- Spectrum Analyzer
- Ku-band TWT
- Signal Generator
- MDC
MDC at Output Port of Ku-Band TWTA

TWTA output

Matched load

To spectrum analyzer

MDC
Measured TWT Fundamental ($f_0$) Saturated Output Power
Measured Second Harmonic ($2f_0$) Power at Port 4 of MDC
Measured $f_0$ Power at the MDC Port 4 & Measured Insertion Loss Between Port 1 & Port 2
Fabricated Ka-Band/E-Band Waveguide MDC

WR-28 waveguide

WR-12 waveguide

Port 1

Port 2

Port 3

Port 4

(a) Laser machined apertures

(b) Thin wall section
Test Circuit for Measurement of Power at Fundamental \((f_0)\) & Second Harmonic \((2f_0)\)
Experimental Setup - Ku-Band/Ka-Band MDC Tests
Measured TWT Fundamental ($f_0$) Saturated Output Power
Measured Second Harmonic ($2f_0$) Power at Port 4 of MDC With & Without the LNA
Conclusions

• Design, fabrication and test results are presented for a Ku-Band/Ka-Band & Ka-Band/E-Band MDCs

• The MDC can be connected directly to the output port of a TWTA with negligible loss of fundamental power – an advantage over harmonic filters and diplexers

• Test results demonstrate sufficient power in the 2nd harmonic for potential space borne beacon source for atmospheric studies